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GROUP INTERFACES: A PROFILE AND A PROTOTYPE

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FOR THE COMMANDER

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13. ABSTRACT *(Maximum 200 words)*

This work addresses human factors aspects of group information technology support -- specifically, novel ways of configuring the technology to meet the needs of teams operating as teams (as opposed to operating as collections of individuals). We outline the relevant background issues and state of the art in group IT support, then analyze what the state of the art represents. Based on our analysis, we lay out a research strategy reversing what we consider a "backward" tendency in prior HCI efforts to support complex interactions in co-located teams with technological configurations initially developed for limited bandwidth distributed messaging. By concentrating on concrete engagements between users and IT artifacts, we generate an analytical framework appropriate to the issues critical in defining a Group Interface (GI), then apply that framework to delineate the design tradeoffs in constructing a GI artifact. We then describe our initial 1994 prototype of a GI artifact -- the Unified Interface Surface (UIS) -- and discuss the results of our usability evaluation of this UIS prototype.

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PREFACE

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INTRODUCTION

This report summarizes a project within the *Collaborative Design Technology Laboratory (CDT Lab)* -- a component of the Design Technology Branch, Armstrong Laboratory Human Engineering Division (AL/CFHD), at Wright-Patterson Air Force Base (WPAFB) in Dayton Ohio. The CDT Lab was established to address collaboration in design and its facilitation through information technology. The CDT Lab was a component of AL/CFHD work aimed at realizing *Computer Aided Systems Human Engineering (CASHE)*, as described in Boff *et al.* (1991). Broadly speaking, the CASHE "vision" entailed bringing advanced *information technology (IT)* to bear on the task domain of human factors engineering in systems of potentially large scale and complexity. In August 1993, Human Engineering Division management directed CDT Lab "... (to) enable and facilitate distributed group decision making, problem solving, and 'concept visualization' for simultaneous engineering and design" by pursuing a mission comprised of the following four tasks:

- Develop and evaluate procedures and protocols optimized to state-of-the-art medias.
- Develop innovative group-human system concepts.
- Model and simulate advanced groupware to assess human and technology demands and implementation feasibilities.
- Transfer emergent group collaboration technical capabilities via CRDA, etc., to industry.

The first explicitly linked our work to the state of the art in the communication media underlying collaborative applications of *information technology (IT)*. Based on the term "innovative" connoting the ability to surpass the status quo, the second task element explicitly linked our work to the state of the art in *human computer interaction (HCI)* as it applies to group IT usage. The third task element explicitly linked CDT Lab activities to the current state of research and commercialization in the research area termed *computer supported cooperative work (CSCW)* and those IT applications for team support termed *groupware*.

The remainder of this report will present one project providing an "innovative group-human system concept" termed the *Group Interface (GI)*. The GI concept was formulated during the autumn of 1993, and the construction of a prototype -- the *Unified Interface Surface (UIS)* -- was accomplished during the second half of 1994. Briefly stated, the Group Interface concept is aimed at providing display, control, and manipulation capabilities at a single physical interface addressable in a manner as "natural" as handwriting (e.g., using a pen or stylus). The GI concept is aimed at overcoming problems with current IT support tools' interfaces which make them difficult to adapt to usage by groups as groups (discussed in detail later in this report). The Unified Interface Surface is an instantiation of the GI concept based on the metaphor of a large interactive whiteboard. We emphasized this type of artifact because:

- Rudimentary electronic whiteboards are already the subject of intensive commercial research and development.
- Such artifacts suggest themselves as leverage applications for USAF team-based operations such as C^3I and battle space management.
- Such artifacts suggest themselves as prototypes of advanced integrated interfaces to USAF systems (e.g., cockpits).
- Such whiteboard-style artifacts are examples of potentially high-volume technology transfers from recent and ongoing DOD and ARPA investments in flat-panel LCD technologies.

Human Factors in Group Support Systems (GSS)

The CSCW literature contains some attempts to identify and address HCI issues relevant for group applications. Such discussions typically concentrate on one of three themes. The first is how already-acknowledged human-computer interface issues pertain to each of the multiple individual users of a groupware system. This tends to treat each group member in isolation -- a position which is not very informative in addressing overall collaboration (cf. Brooke, 1993). The second is identifying those features of group interactivity (e.g., turn-taking) which should be supported (or at least taken into account) by the artifacts team members employ. This entails extending conventional HCI accounts to address a unit group rather than an individual user (cf. Hewitt and Gilbert, 1993). The third is to generally describe the affordances of a collaborative medium, typically with respect to one or both of the previous two themes (e.g, Gaver, 1992). Our specific interest was interfacing IT with entire groups -- i.e., configuring IT artifacts to directly support teams operating as teams (as opposed to operating as collections of individual end users). To that end, we attempted to address the three HCI themes noted above, while avoiding their potential dangers -- the first's potential blindness to interpersonal factors, the second's potential blindness to technological affordances, and the third's potential blindness to target user needs.

Our line of argumentation concerning the state of the art and the directions for positive improvement are focused on the field of *group support systems (GSS)*. This is the more contemporary and generic alternative to the better-known term *group decision support systems (GDSS)*, which denotes IT artifacts supporting groups making decisions. Overlapping terminology includes: *DSS (decision support systems)* (e.g., Huber, 1980; 1981); *meetings augmentation* (Wilson, 1988); *EMS (electronic meeting systems)* (Dennis *et al.*, 1988); *real-time computer conferencing* (Ellis *et al.*, 1991); *electronic meeting rooms* (Ellis *et al.*, 1991); *electronic board rooms* (DeSanctis & Gallupe, 1987); and *computer-supported conference rooms* (DeSanctis & Gallupe, 1987). Our research interests are not limited to "decision making" per se; they include group knowledge acquisition, planning conferences, participatory / user-centered design, and educational technologies in support of collaborative training / learning. However, in terms of research orientations (as a field) and deployed products (as a class of artifacts), GDSS / GSS best exemplifies the topical foci and type(s) of IT support we see as critical to our other interests. Such systems are diverse in scale, functionality, complexity and cost, but they all support collaboration through a mixture of two distinct approaches to intervention.

The first approach is to provide *technological support*. GSS represent a confluence of work in (1) decision support systems (DSS) for specialized individual users (e.g, managers); (2) communication support systems (e.g., computer networks; e-mail); and (3) data display technologies (e.g., easy to use graphic interfaces; projection displays). The descent from earlier DSS work has preserved a focus on making available as much relevant data as possible to the decision maker. The integration of communications support allows multiple users to (1) access incoming referential data; (2) co-generate documentation of their emerging consensus and (3) conduct this activity in diverse time/space permutations. The influence of data display technologies affords co-located groups common access to complex data displays.

The second approach is to provide *interactional support*. The shift from single-user DSS to multiple-user GSS requires attention to group interactions in a decision process. This provides the juncture where GSS work meets work from cognitive and social psychology, management studies, etc. Procedurally, GSS have entailed (1) (at one extreme) direct application (if not embodiment) of structured decision making strategies; and (2) (at the other extreme) rich environments for flexible interaction among collaborators, with little or variable adherence to a specific protocol.

Throughout this range of support, users are provided with human as well as IT support in the form of facilitators (Viller, 1991) -- participants specialized in aiding collaboration. Facilitation generally consists of aid in the form of guidance or coordination of the meeting process and/or operational assistance through managing the tools supporting the given meeting.

GSS cannot, therefore, be addressed with respect to one or the other interventional modality in isolation. To remove the interactional aspect would leave only LANs, group editing tools, databases, and the like. To remove the technological aspect would leave only structured group activities. This dualistic nature is consistent with the dichotomous character of the CSCW field's interests (e.g., Bannon & Schmidt, 1989) and its practitioners' tendency to tilt toward either "<u>computer support</u> for cooperative work" or "computer-supported <u>cooperative work</u>" (Whitaker, Östberg & Essler, 1989).

The human factors issues we shall discuss, however, are of general applicability to any IT system whose usage relies upon collaborative accretion of a shared information base. This scope subsumes most groupware. Bannon and Schmidt (1989, p. 364) identify "sharing an information space" as a "core issue for CSCW," De Michelis (1990) cites "information sharing" as the key support for collaborative activity, and Robinson (1991) cites *shared information space* as one of the most important "CSCW specific concepts." Both Robinson (1991) and Bannon (1991b) credit Thompson (1984) with this concept, which is implicit in Engelbart's (1963; 1982) seminal visions of shared IT applications and (termed *shared environment*) Ellis *et al.*'s (1991, p. 40) definition for "groupware."

Analyzing The Sources Of Current GSS Limitations

The term "GSS" has been applied to a variety of artifacts spanning the full range of time / space permutations (e.g., Kraemer & King, 1988), and we recognize that diversity. What we question is taking HCI "styles" devised for distributed computer-mediated communication and uniformly applying them to non-distributed (i.e., co-located) cases. Current environments for synchronous, co-located GSS usage are a mix of: (1) conventional conference room architectures designed for natural conversation, but "linear" and "flat" documentation (i.e., paper); and (2) IT providing novel information formats (e.g., hypertext; 3-D graphics), yet constraining discourse to the "linear" and "flat" style of text-based remote messaging. In such a scenario, the channel of group communication (the *conversation space*) is commonly shifted from the room's *physical space* to the computers' *data space*. The physical space continues to be employed as a conversation space only for (1) the *facilitator* brought in to manage the disruptive effects of the aforementioned channel shift and (2) discourse falling outside the scope of the structured GSS protocol. In effect, *today's GSS products invoke the style of a distributed data conference in supporting even co-located meeting participants* (Whitaker, 1994). Possible partial explanations include:

• *The functional specialization (i.e., division of labor) which typified the organizational milieux into which IT and data communications were initially introduced.* The emphasis on team-oriented professional activities (e.g., TQM) is a relatively recent trend. By the time the organizational work styles were tilting toward group work, technological architectures designed for isolated, individual workers (e.g., keyboard / CRT combinations; individual terminals / workstations) were mature and market-dominant. It is still the case that "computer systems" (i.e., typical stand-alone hardware packages) are configured for the single user.

• *The cost of installation for early IT systems.* Early IT systems were extremely expensive for their time. As such, IT investments were typically aimed at high-performance or mission-critical applications. Applications in support of collaborating groups were generally limited to functional collaboration, which (in conjunction with the aforementioned specialization) typically meant parallel access onto shared data (e.g., databases). Applications in support of *communicating* groups were generally limited to situations wherein the computer overcame problems of complexity

and/or distance (e.g., the origins of our current Internet as a DOD backup C^3 system). Early computer support for communications emphasized creation, transport, storage, and retrieval of text units (e.g., email; net news). By the time that computer-mediated communications became cost-feasible for a broader population, technological architectures for relatively narrow applications were mature and market-dominant.

• *The initial application of IT to distributed group decision making.* The earliest group decision processes conducted with computer support were conferences involving spatially and temporally distributed participants. Hiltz and Turoff (1993) provide an overview of this historical development. Such conferencing applications were naturally constrained to text-based messaging, due to their distributed nature and to the state of computer-mediated communication at the time of their inception (the late 1960's - early 1970's). By the time IT became cost-feasible for co-located decision making groups, distributed procedural architectures for team decision making (especially as supported by computers) were mature and widespread.

• *The initial application of co-located group IT support in the service of production, rather than communicational tasks.* The GSS work at the University of Arizona, whose commercial derivatives currently dominate the marketplace, began as the PLEXSYS project. The broader application of such facilities to management decision making was a later emphasis. The computer-supported collaborative rooms developed for PLEXSYS were initially aimed at (e.g.) team software programming and review. Such a focus on production tasks is consistent with the result -- a primary attention to commonly-accessible textual data (e.g., program code) via individual workstations.

• *The relatively late arrival of graphical user interfaces (GUI) and direct manipulation interfaces.* During the period(s) when the aforementioned events were in motion, computer usage was overwhelmingly text-based, even for the individual user at his/her terminal. Although *distributed* computer-mediated communication is still mainly text-based, the emergence and proliferation of GUIs has long provided the means for enriching data display for single sites (e.g., meeting rooms). Furthermore, these historical events occurred during the period when *all* computer interaction (for input and control) was necessarily done via keyboard.

In effect, 1960's-era technological solutions for distributed collaboration have become the paradigmatic approach to supporting all collaborative scenarios and the de facto apparatus for effecting such support. The best illustration of this claim is to be found in Engelbart & English (1994) -- the historic December 1968 presentation of the NLS system at the Fall Joint Computer Conference in San Francisco. The IT innovations first presented on that occasion included: word processing, outline processing, hypertext, direct manipulation devices (the mouse), on-line messaging, electronic mail, on-screen document sharing, desktop data conferencing, and desktop video conferencing. In terms of basic functionality, today's groupware has not yet extended this toolkit. The final proof of this illustration is that the earliest facility capable of computer-supported meetings was the demonstration testbed for Engelbart's work -- the ARC (Augmentation Research Center) at SRI (cf. Engelbart & Lehtman, 1988).

In the mean time, however, the application scenario is shifting. It is becoming increasingly possible to: (1) transport, share, and manipulate graphical data, audio, video, and hypertext over networks and (2) exercise more sophisticated and varied control in networked IT (e.g., client-server architectures; distributed applications). Innovations emergent from individual workstations are now proliferating back through, and to, networks. Where the early 1980's were marked by the rise of the microcomputer as an individual productivity tool, the early 1990's are distinguished by the rise of the network as the composite "system" of interest. There is no more convincing evidence of this shift than the expansion of Internet, the simultaneous explosive growth of multimedia networking (e.g., the World Wide Web), and the concomitant push to overhaul our available data communications capacities (i.e., the *National Information Infrastructure*, or *NII*,

initiative).

The prospect we face entails widespread usage of networked IT by an expanding range of workers (and especially *groups* of workers) within organizations some (it is often suggested all...) of whose structures are becoming "flat" and fluid. Networks are the driving motivation for conceiving, developing, and deploying IT support for group productivity. However, such group productivity in tomorrow's networked workplace is not likely to be effectively enhanced by applications derivative from yesterday's networking modalities, which as we have seen were constrained by technological limitations and created for highly specialized individual workers in hierarchical organizations.

Our Research Strategy: Let the Co-Located Scenario Inform Support for the Distributed Scenario

As discussed above, human factors problems of GSS derive from applying the mode of IT support initially justifiable for a distributed collaborative setting into all (including co-located) scenarios. The human factors innovations which helped overcome the constraints of such distributed work (e.g., shared graphical displays, messaging) are now the dominant operational style in situations where those constraints do not or need not pertain. One example is the fixation on combining communications and collaboration capacities within the framework of individual computer workstations deployed on a one-user/one-machine basis. This sort of deployment was the only one feasible 30 years ago, when the capacities of the available technology determined the mode of end user deployment (individual workstations / terminals; textual messaging, etc.). Reciprocally, the geographically / temporally distributed work scenario was the only one potentially critical enough to justify the much higher deployment costs of that era. As organizational and other factors compelled a shift toward more collaboration, IT developments continued along the lines for which IT was initially configured for collaborative activity -- i.e., the distributed scenario.

We believe that human factors / HCI research for workgroup applications has been proceeding in a fashion which seems "backwards." The most "natural" or "ecologically valid" (cf. Brunswik, 1956) reference testbed for collaborative activity is the co-located scenario. Knowledge of this most natural style of collaboration should be the basis for configuring IT applications for even the most "unnatural" (i.e., distributed) scenarios. By this we mean that effective functionality in the more unnatural scenario(s) would be facilitated by extending or projecting functionalities proven effective in the most natural scenario. Historically, this has not occurred. Instead, the available means for addressing mission-critical collaborative work in the most unnatural scenarios has become the default support style for all collaborative work in even the otherwise most natural settings (i.e., the same room).

The first thrust of our research and development has therefore been directed toward co-located task-oriented teams. After more than a decade of GSS work, there remains much to be learned about behavioral and social aspects of team work (Kraemer & King, 1988; Docherty, 1992). One part of the CDT Lab research has been directed toward studying actual design teams and experimental subjects to learn more about human factors in collaborative settings relevant to IT support. Because that work is described in Whitaker, Selvaraj, Brown & McNeese (in press), we shall not detail it in this document. Instead, we shall concentrate on reporting two lines of work aimed at technological innovations in group IT support. The first is our formulation of *Group Interfaces* as paradigmatic goals, and the second is our development work focused on an example of such a Group Interface artifact -- the Unified Interface Surface prototype.

A New Paradigm for Collaboration Support: The Group Interface (GI)

For the synchronous, co-located scenario, we have explored the means for leaving the conversation channel(s) in a natural setting (the physical space) and (in contrast to the current state of affairs) maximally shift access to the data space into the physical space (i.e., the room). Combined with innovative modeling / presentation / annotation software, such a proposed arrangement:

(1) prioritizes *group* interactions (as a whole; in the natural conversational space) over a collection of *inter-individual* interactions (isolated; constrained by the data space)
(2) maximizes the affordances for, and ease of, engagement of all participants with the IT support
(3) provides an interface to IT support tools which promotes as "natural" a style of situational engagement in the meeting as possible
(4) reduces the restrictions induced by addressing physical neighbors solely through the "virtual" forum of the data space (itself accessible only via the CRT screen).

We use the term *Group Interface (GI)* to denote a unitary or composite IT artifact configured to meet these requirements. We chose the term to emphasize interaction *by a group as a group* with their mutual IT resources.

The above allusion in point (4) to "virtuality" allows us to illustrate our goals in comparison to the most sophisticated current HCI technologies. Innovative control and display devices (e.g., "data gloves"; helmet-mounted displays) have recently been strongly associated with individual users engaged in or with a *virtual reality (VR)*, i.e., an artificial milieu in which he/she operates as if wholly immersed therein. Forcing co-located group members to interact as if at a distance is consistent with VR -- i.e., engagement of a user within an artificial milieu. No matter how sophisticated, current and prospective VR technologies are inherently impoverished by comparison with the "natural" sensorium. If multiple users were to be expected to interact within such an artificial milieu this impoverishment would be compounded, no doubt to the sort of detrimental effects already noted for GSS in particular and computer-mediated communications in general.

The notion of collaboration in virtual reality is fascinating, and some are already suggesting VR as the next venue for distributed conferencing and GSS (e.g., Benford & Fahlén, 1993). However, VR cannot (by itself) provide a solution to the communicational deficiencies we have delineated, either now or in the near-term future. First, VR is best suited for bringing together spatially distributed collaborators. It is difficult to see how VR could usefully support co-located groups except as a common means of engaging with something other than themselves -- e.g., a simulation. Thus, VR can be seen as a candidate technology for enriching subject matter visualization in a meeting, but not necessarily for enriching the communicational interaction among participants. Second, it is difficult to foresee, much less predict, a time when VR would be cost-competitive with (e.g.) video teleconferencing for emulating a face-to-face atmosphere in a distributed meeting. We seek to augment and extend computer-supported collaboration opportunities generally, not just for a few cost-intensive applications. Finally, the bandwidth does not currently exist for full-scale multi-party VR conferencing. Neither is it assured that NII will deliver sufficiently broad access to sufficiently great bandwidth to make VR conferencing viable for general usage. We believe that widely-usable, cost-competitive collaboration tools are the wiser priority at this time. Such products can provide the leverage for NII, which will itself be the initial step in creating the conditions for planning and realizing the even greater capacities requisite for VR conferencing.

In contrast to the VR path, our co-located scenario emphasizes the augmentation of a "real world" space with unobtrusive IT support artifacts. Mark Weiser of Xerox PARC coined the term *ubiquitous computing* or *ubicomp* to denote this complement to VR (Weiser, 1991; 1993a).

Weiser (personal communication, November 1993b) explains: "...I contrast ubicomp (or embodied virtuality) with VR like this: VR immerses the person in information in an artificial world, while ubicomp brings the information out here with us into the real world. Both are engaged in a kind of immersion, but ubicomp aims to augment the existing immersion, VR to replace it. Thus they are kinds of duals ... or inverses."

An orientation emphasizing ubiquitous computing requires us to take a necessary step "back" to re-evaluate how group interactions in a "natural" co-located situation occur and how they can be usefully supported with IT. As Weiser (1993a) points out, this is not the same thing as developing either a better graphical user interface (GUI) or multimedia capacities. Those two goals concern how to make an unavoidable engagement with a computer more effective or how to expand the range of data provided at the point of that unavoidable engagement. In other words, framing the problem as either a GUI or a multimedia deficiency is to overlook the (potentially excessive) demands of addressing the computer on its own physical and functional terms. He goes on to summarize: "The challenge is to create a new kind of relationship of people to computers, one in which the computer would have to take the lead in becoming vastly better at getting out of the way, allowing people to just go about their lives." (Weiser, 1993a, p. 76)

The applicability and relative merits of different media remain issues for ongoing research (cf. Sharples et al.,1993; Luff, Heath & Greatbatch, 1992). Different support media provide distinct affordances (e.g., the necessary linearity of audio tape; the relatively unrestricted spatial organization of note cards) affecting usability in a task setting. This diversity implies that one cannot simply assume that any medium works as well as any other for a given task. To the extent the task drives implementation, procedural parameters help determine the sort of affordances novel media should provide (cf. Luff, Heath & Greatbatch, 1992). In turn, the technology implemented will help determine how flexibly the task can be accomplished (cf. Robinson, 1991, on *articulation work*).

GSS installations have been augmented with non-computer media such as telephones, flipcharts, audio-visual displays, whiteboards, and other shared drawing surfaces (Johansen et al., 1991; Suchman, 1988; Tang, 1989). In the CSCW / HCI literature the affordances of such conventional media have been typically addressed in terms of how they map onto the characteristics of software support for geographically distributed teams (cf. the numerous "electronic whiteboard" applications reviewed in Brinck and Gomez, 1992). In contrast, we have concentrated on the co-located setting and sought to merge the characteristics and utility of these conventional tools with the power and flexibility of IT. The first step was a critical analysis of the affordances provided users by current conventional tools. In the following section, we shall outline this effort's resultant framework and its ramifications for formulating group interfaces. We have then moved forward to identify, obtain, and integrate current IT capabilities in an innovative prototype of the solution thus formulated. This prototyping effort will be the subject of the second section following.

Dimensions Of Human-Computer Interaction

Real-time human-computer interaction can be characterized as an interplay of display, control, and manipulation actions effected by the user and data transformations effected by the computer. These actions are conducted with respect to specific points of interaction afforded by the computer. They are typically aimed at generating some unit product. In outlining our prospective technological innovations, we have concentrated on these two aspects of this interplay as: (1) the *physical / functional engagement* between human and technological artifact and (2) the *logical / manipulative engagement* of the human with an informational artifact. The physical / functional engagement pertains to the tools of a productive interaction (e.g., keyboards), while the logical / manipulative engagement pertains to the production unit itself (e.g., a text file). In the following sections we shall detail relevant aspects of these two forms of engagement, explain how we

characterize HCI issues with respect to them, and how we propose to improve group IT support based on this analysis.

Physical / Functional Engagement: An interplay with surfaces

We characterize the points of physical / functional engagement as *surfaces*, of which there are three primary types:

- *Data display surfaces* These are the surfaces at which data is presented -- e.g., computer monitors, large projection screens, and the like.
- *Display control surfaces* These are the surfaces through which presentations of data are manipulated. Examples include the mouse and keyboard (for command input only).
- *Data input surfaces* These are the surfaces through which data can be entered or modified. The leading example is the keyboard (for text entry only).

For the individual user, there is typically one physical subcomponent of his / her workstation for each surface's function, as illustrated in Figure 1 below. There are, however, possibilities for overlap, particularly between the display control and data input functions. On the Apple Macintosh™, both these functions may be fully accomplished using the mouse (although text entry gets tedious when done via 'point and click'). By the same token, they may both be accomplished using the keyboard, to the extent the software developer has incorporated keyboard equivalents for 'point and click' commands.

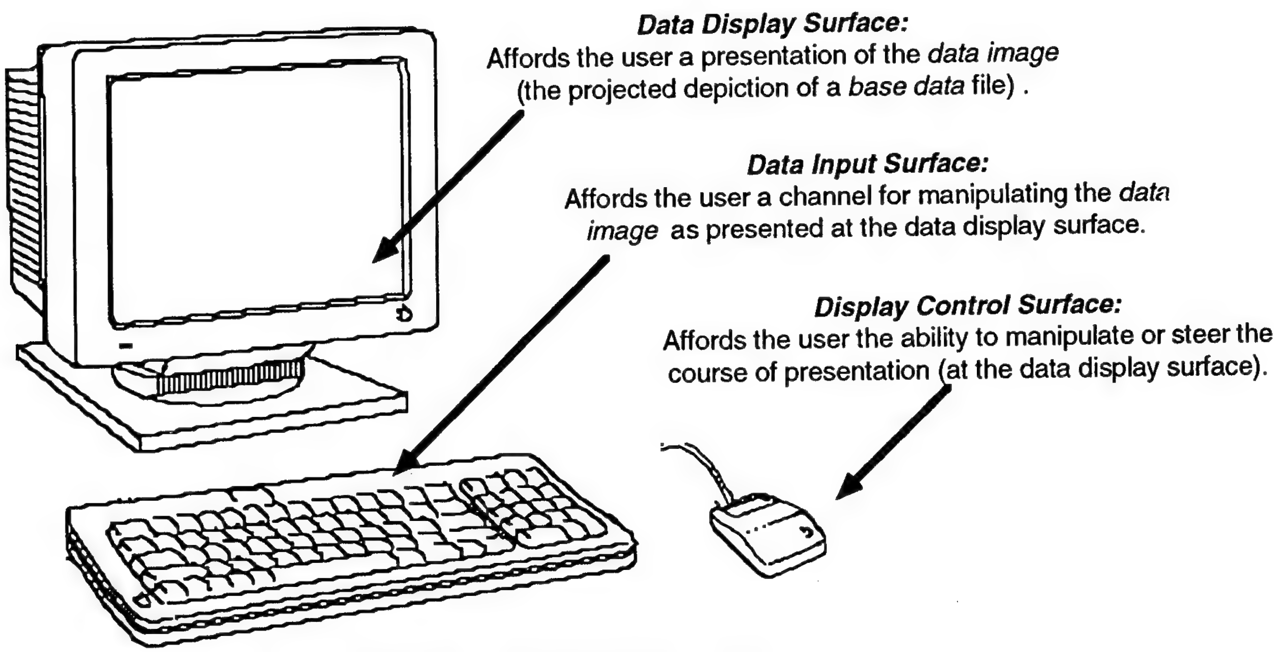


Figure 1: The three surfaces for human-computer engagement

The CDT Lab proposes group interface (GI) technologies in which these three surfaces are brought into the closest feasible physical and functional proximity to provide maximally unified zones of human / computer interactivity. The functionality of a full-scale group interface is already foreshadowed, but not yet accomplished, in recent IT innovations. At this point we can begin our analysis of the state of the market vis a vis our GI vision.

Newly-emergent pen-based devices and electronic whiteboards offer ways to overcome

yesterday's interface limitations, but current products do not provide the unified display *and* control / input capacities we see as critical in group interfaces. A couple of specific examples will illustrate this "state of the market." With respect to pen-based devices, the Apple Newton ™ represents an example of a *Personal Digital Assistant (PDA)* -- a portable, keyboard-independent "note pad" which professionals could easily bring into a meeting room. We have commonly used the crude description "giant wall-mounted Newtons" to illustrate what a GI artifact might be. At this date, Newton PDAs make provision for connectivity to, and data file transfer into, PC and Macintosh platforms. This makes them amenable to "writing" initial comments for eventual inclusion to a shared information space and/or projection onto a group interface display. However, PDAs do not yet offer the ability to serve as a control device for larger computers. As such, a PDA-accessible version of a GSS would allow meeting participants an input channel for text, but no channel for direct control over (e.g.) the group display.

What are the most closely analogous devices for group use? Ignoring products exclusively for data display, we find that the simplest such commercial offerings provide data input capabilities (e.g., generating a bitmapped picture of writing on the whiteboard surface) without data display and display control. For example, the SoftBoard™ from Microfield Graphics, Inc., allows users to draw upon a large whiteboard surface, with the result being available within a connected computer as a graphical image (drawing). This image can then be manipulated and shared subject to the limitations of the resident computer(s). Access to this image is limited to the ability of the computer to display, transmit, receive, or reproduce it. SoftBoard does not permit the user to control the computer(s) from the drawing surface itself. Furthermore, since SoftBoard is strictly a graphical input device, it is not possible to either display (at the board surface) or manipulate (e.g., edit) an extant image. Other devices allow for data display and display control, but make no provision for data input (e.g., controlling a projection device from the display screen). For example, Proxima Corporation markets equipment (Cyclops™) allowing a presenter using a computer-driven (e.g., LCD panel --> OH projection) display to control the projecting computer from the projection surface. Before we can analyze the most sophisticated available devices, we must first discuss the other side of human-computer interaction -- logical / manipulative engagement.

Logical / Manipulative Engagement: Bridging the transcription gap

We characterize points of logical / manipulative engagement in terms of how directly the user engages the final production unit. Most generally, human-computer interaction produces new or modified *base data* -- binary codes at the lowest level of this interaction (on the computer side). Software applications (e.g.,word processors) apparently mediate user actions against files of base data, which are both the interaction's production output and the input for subsequent interactions of the same type. This appearance does not mean that the user necessarily interacts with the base data file(s) directly. He / she may view a derivative display representation rather than the data file itself (e.g., a bitmapped depiction of ASCII text data). He / she may effect control changes in the display image without actually modifying the data file itself (e.g., zooming in on or scaling a bitmapped picture). His / her data input may only conditionally accrete to the base data file (e.g., keystrokes buffered pending a 'write' command; graphical changes subject to retraction via an 'undo' command). To provide contrast with the base data files, we term these intermediate items *data images*. The surfaces outlined in Figure 1 do not necessarily provide user access to the base data, but only to the available data image(s).

This differentiation between base data and data image has been made generically, and one may question how it relates to problems in group IT support. The answer lies in how this distinction relates to assessing the critical groupware concept "shared information space" for concrete instances of collaboration. In our facilitated design sessions with multidisciplinary design teams, the immediate product of collaborative effort (e.g., a diagram drawn on a whiteboard) is of little subsequent use to the design team members until it has been made available across distance (e.g.,

broadcast to everyone) or across time (e.g., archived by everyone). The initial *data image* on the whiteboard must be *transcribed* into some other form of *base data* whose distribution and preservation disengage the collaborative payoff from its initial inked depiction. The operationalization of this difference between the data image manipulated within the session and the base data exported as that session's product constitutes a *transcription gap*. Because this example concerns one session in isolation, we term this an *intrasessional transcription gap*. Such an operational problem operant across sessions (e.g., getting the spreadsheet figures generated in session A inserted into the report co-edited in session B) we term an *intersessional transcription gap*.

Bridging such transcription gaps can be costly, as CDTeam learned in the course of its research on collaborative design activities. In the CDTeam's observational studies, we found that transcribing our handwritten meeting notes into electronic files consistently entailed a *transcription ratio* (transcription time to meeting time) varying from 2:1 up to 5:1 (cf. Whitaker, Selvaraj, Brown & McNeese, in press). These transcription gaps were issues for improvement in our facilitation of group sessions, too. In our earlier knowledge elicitation work, intrasessional transcription gaps were minimized by (e.g.) compiling, printing, and distributing final versions of generated knowledge representations as soon as possible. Later, the use of software capable of printing out the file generated in the original knowledge elicitation session further minimized this gap. The fact that this software permitted generation of a persistent base data file which could be modified in subsequent sessions addressed the intersessional transcription gap.

This local experience parallels earlier experiences in the CSCW / groupware community at large, where rapid delivery of compiled meeting data was increasingly demanded by clients and feed-forward of generated material increasingly became a basis for claiming productivity gains (Losada, Sanchez & Noble, 1990; Docherty, 1992; Nunamaker *et al.*, 1991). Transcription gaps have become even more critical, as CSCW researchers increasingly link successful collaboration (especially decision conferencing) with rapid intrasessional feedback (e.g., Eden & Ackermann, 1992) and newly-proliferating design practices such as concurrent engineering increase the demands for (and demands on) intersessional feed-forward.

We are now ready to assess the most sophisticated available product analogous to our group interface vision -- the Xerox LiveBoard™ (Xerox Palo Alto Research Center, 1992; Weiser, 1993a). The LiveBoard is a large cabinet housing a rear-projection system whose screen (data display surface) is also the locus of manipulations for controlling the projected image (display control surface). As for data input, LiveBoard users may graphically (i.e., with bitmapped marks) annotate the displayed image at the same surface (data input surface) analogous to using a "paint" program (e.g., MacPaint). For both display control and data input, the manipulations are accomplished using a wireless infrared pen device. On the surface, the Liveboard accomplishes the unification of the three surfaces for physical / functional engagement.

It is only after considering the issues of logical / manipulative engagement that we can explain why this is still not quite enough. We have carefully characterized data input with the Liveboard as *annotation* -- in the same sense that one might annotate a printed page with a red marker. The key point here is that such data input is limited to the *data image*, in the sense that a picture of the annotation is the only result of the annotation. It is not a direct manipulation of the original (prior) base data. This sense of the term "annotation" is precisely that used in characterizing collaborative applications within the World Wide Web (WWW) as "annotation systems." This disjunction of annotated data image from initial base data necessarily introduces a transcription gap which must be overcome before the annotation can effect a permanent change in the original base data. Regardless of our respect for Xerox's product, we still aspire to something one step further -- an elimination of intrasessional transcription gaps concomitant with unification of the surfaces for user engagement.

The Interrelationship of Transcription Gaps and Interface Unification

There are concrete human factors tradeoffs to be considered in the current state of the art in transcription and interface unification solutions -- tradeoffs which must be considered in developing group interface artifacts. These tradeoffs are typical and representative of basic human factors issues (e.g., enhanced interface control with a corresponding decrease in display legibility). We shall illustrate such tradeoffs with regard to CDTeam experiences in group knowledge elicitation sessions. In these sessions, facilitators aided subject matter experts in generating *concept maps* -- graphic diagrams of nodes and links representing concepts and their interrelationships (cf. Zaff, McNeese & Snyder, 1993). Graphic knowledge representation schemata such as concept maps are simultaneously laudable for their facile interpretability and notorious for requiring large amounts of depictive "real estate" (display area).

As noted above, reducing transcription gaps in concept mapping was accomplished by progressively relying on software as the medium of initial elicitation. The offsetting factor was that this reliance on electronic mapping entailed providing client feedback through projection of computer monitor displays (data images) consistently insufficient for portraying the entire product (the concept map) at one time. Generally stated, in the co-located situation, a potential payoff (vis a vis reduced transcription) of intrasessional IT uniformity may be more than offset by the limitations of both current interfaces to display, and team members to manipulate, the data images. Conversely, the potential payoffs of group interface unification may be more than offset by the resultant limitations in transcribing data images into useful base data and vice versa.

The effects of such tradeoffs can be further illustrated with reference to the individual and group knowledge elicitation sessions analyzed with respect to "depictional lock-on" in Whitaker, Selvaraj, Brown & McNeese (in press). In the individual case, the knowledge transcription was done directly into electronic form, with the result projected on a 6' x 8' screen. The interviewee's contributions quickly filled up the screen, and subsequent elaborations on the structured knowledge representation typically required his first navigating to some portion of the data image outside the area currently displayed. Much auxiliary discussion and activity was directed to overcoming this sort of display limitation. In the group case, the knowledge transcription was initially done on a large array of whiteboards. As the knowledge elicitor proceeded, another CDTeam member seated at a computer nearby transcribed the emerging map into an electronic format. We projected this additional (electronic) display off to one side, but it never became the primary focus of the group interviewed. In the individual case, we minimized the transcription gap at the expense of display utility. In the group case, we maximized the display utility but introduced a transcription cost (the second person doing the transcription). In both cases, the large display surface was appreciated by the client(s). In neither case was the display surface integrated with the control or input surfaces; in fact the control and input functions were never directly available to the clients.

The Unified Interface Surface (UIS): A Prototype Group Interface

During 1994, the CDT Lab undertook the prototyping of a Group Interface artifact. Generally speaking, the goal was to merge the affordances of a conventional whiteboard with the flexibility of a computer-based system. This meant that we sought to provide interactive data display, interactive control capabilities, and direct pen-based data input within one integrated user interface. Overall, we specified that the display present information clearly and provide the means for easy, direct changes to that information (either text or graphics) through as integrated a suite of interface surfaces as possible. Because this entailed merging all three surfaces (display, display control, and data input) at one physical surface, we labeled the prototype the *Unified Interface Surface (UIS)*.

Basic Specifications for the UIS Prototype

There were to be three components to the eventual UIS prototype: a rear-projection *data display surface*; a large, high resolution pen-input sensor for the *display control surface*; and text recognition software which (in conjunction with the pen-input sensor) would afford a direct *data input surface*. The following paragraphs outline our basic specifications for the display, control, and input characteristics of the final (second-stage) UIS prototype. These set the eventual goals toward which we would work in developing the first-stage UIS concept demonstrator.

Display Characteristics of the Planned UIS Prototype. We specified that a small to medium sized group (e.g., 8 to 12 people) be able to view the display clearly. The target display resolution was loosely defined to approximate that of a 17" color monitor display magnified via an LCD projector (i.e., our CDT Lab group display equipment). The target range for group viewing distances was to be 2-15 feet, based on the size of the CDT Lab Group Workspace. Based on our experiences with conventional whiteboards and projected computer displays, we estimated the minimum necessary size for such a prototype to be on the order of 40 to 48 inches across. We specified that the prototype be capable of displaying a working data image at an acceptable brightness level, without pixel jitter, and without undue glare or reflections from the display surface. To avoid the glare and reflection problems, we prioritized display equipment which did not rely on "front projection." This rejection of front projection was also consistent with our desire that users standing and working at the UIS would not occlude the data image.

Control Characteristics of the Planned UIS Prototype. We specified that display control for the UIS prototype be effected by "direct manipulation" (cf. Shneiderman: 1982; 1983), and that this direct manipulability be effected in a "hands-on" fashion at a surface as minimally differentiable from the display surface as possible. We agreed that using a handheld stylus or pen at the display surface (analogous to the use of a marker on a whiteboard) would be an acceptable solution. It was agreed that using such a stylus device should entail manipulations no more complex than the pointing and clicking maneuvers of (e.g.) using a mouse with the Apple Macintosh™ interface.

Input Characteristics of the Planned UIS Prototype. We specified that the UIS prototype be capable of text input using a pen or stylus. This decision was intended to: (1) free users from the need for a remote keyboard; (2) free users from the need for typing skills; and (3) maximally unify the auxiliary devices (i.e, the stylus) needed to manipulate the unified interface surfaces. The recognition software was to be capable of recognizing text with an accuracy rate comparable to state-of-the-art commercial pen products. This accuracy was to be evaluated as a tradeoff against ease of input (e.g., minimal need for special moves by the writer) and readiness for a new user to input text (e.g., minimal requisite ramp-up time for user or recognizer training).

Multi-User Characteristics of the Planned UIS Prototype. If possible, the eventual UIS prototype would approximate the multi-user affordances of the envisioned Group Interface by allowing for cordless pens and simultaneous tracking of multiple pens. The number of such users to be supported was left open at this time, because (1) tracking multiple users' pens would tax the available technologies and (2) it was unclear to what extent multi-user capabilities' were required for the eventual prototype. Typically, only one person uses a whiteboard at a given moment in a formal meeting or presentation. Brinck and Gomez (1992) found that in informal office communication, most conversations utilizing whiteboards involved only 2 or 3 people.

Implementation Plan for the UIS Prototype

Based on the requirements specifications, we developed an implementation plan for the UIS prototype. The first step was to draft an activity timeline. The UIS prototyping process was planned to proceed in two stages. The first stage, to be completed by the end of calendar 1994, was to construct a proof of concept demonstrator incorporating direct manipulation control, color display, and data input capabilities at one physical surface. For the purpose of proving the concept (with reasonable economy), this initial prototype would be configured as a single-user

workstation. If the proof of concept demonstrator proved sufficiently successful to attract additional funding, the second stage was planned to expand the initial prototype's features to a larger format specifically dedicated to group usage. Due to the conditional nature of the second-stage work, we did not specify a milestone for its inception. We hoped to accomplish the second-stage prototyping during calendar 1995.

The next step in the implementation plan was an extensive market review of available display, control, and handwriting recognition products. It soon became apparent that the largest number of microcomputer products available for use were targeted for MS-DOS PC's running Microsoft Windows™. Because the CDT Lab was an exclusively Apple Macintosh™ installation, we concentrated on the smaller (but no less sophisticated) set of products aimed at the Mac market. It was our opinion that any additional costs for selecting from a smaller candidate pool or adapting a non-Mac product for our use were more than offset by the higher potential costs of acquiring PC equipment and/or adapting a PC-based solution for demonstration in the CDT Lab environment.

<u>Implementation Specifications for the UIS Prototype</u>

Our initial UIS concept demonstrator was intended to illustrate the "vision" of a Unified Interface Surface, not necessarily to finally accomplish all the goals of our requirements specifications. To achieve the best such illustration at minimum cost, we drafted implementation specifications matching our basic specifications against a tractable set of available or achievable technologies identified from our market survey. By this point, we had identified a number of tradeoffs affecting the technical and / or budgetary feasibility of building the first-stage UIS concept demonstrator. This section will describe our assessment of some such tradeoffs and their influence in translating the basic specifications and the results of our market survey into the implementation specifications.

One motivation for pursuing our Group Interface vision was the fact that ARPA had recently invested heavily in ramping up American development and manufacturing capacities for flat-panel LCD displays. In the June 1994 *DOD Detailed Technology Area Plan on Human Systems Interface*, such displays were cited as critical components of projected military IT applications such as virtual reality interfaces, heads-up displays, and communications systems. Promoting an American production capacity for this critical technology was a strategic response to current Japanese dominance of the LCD marketplace. Our analysis of these factors led us to conclude that: (1) flat-panel LCD displays would remain a critical DOD technology for the foreseeable future; (2) the market costs of such displays could be expected to drop as production and market competition increased; and (3) the size and performance characteristics of such displays could be expected to increase over the next 5 to 10 year period.

We therefore laid out our UIS prototype specifications in such a way as to contribute to a development path toward a target of Group Interface artifacts implemented on large-scale flat-panel LCD displays. The primary impact this had was to limit the range of pen / pointer devices which we could incorporate into the prototype. Devices whose pen / pointer tracking relied on sensors mounted elsewhere than at (or around the periphery of) the display surface were ruled out on the grounds that no such device we reviewed could be adapted to the target LCD flat panel deployment. Devices whose tracking relied on specific characteristics of displays other than LCD displays were similarly excluded. To give a particular example, this latter exclusion eliminated light pens from consideration, insofar as their functionality depends upon a cathode ray device and cannot be directly applied to an LCD device.

The pen-input sensor chosen for the second-stage UIS prototype was a conventional glass touch screen technology -- an analog resistive device employing a corded pen to make non-pressure sensitive contacts on a clear glass surface. The sensor is built from a single piece of water-clear etched glass, the back side of which could be a projection surface. Since there would

be no air or other gaps between the imaging surface and the front (pen-accessible) surface, there would be minimal parallax between pen-tip and the data image display. The result would be a sensor which provides pen input at high resolution without degrading the clarity of the projected image. Because this is an analog sensor, a single corded pen is the only input device that can be used, not a finger or other stylus. The pen's marking resolution was 4095 lines in both the horizontal and vertical axes. On a 40 inch diagonal display this would provide more than 5 lines/mm resolution. The sensor device computes and transmits pen location at a rate of 150 Hz. Our assessment was that these performance characteristics were sufficient for the concept demonstrator.

This glass touch screen technology was already available as custom units in stock sizes. For example, a 20" diagonal touch screen unit could be obtained at a cost on the order of $500. To meet our projected goal of a 40-48" size, one of these units would have to be custom built at a larger than normal size. According to our initial market review, a custom-built 40" diagonal unit would cost on the order of $10,000, and a six-foot custom-built unit (requiring special subcontractor production) could conceivably be ordered for on the order of $100,000. Owing to the expense of these custom-built units, we elected to hold the first-stage UIS concept demonstrator to a 20-inch size. Because of this decision to hold the concept demonstrator to a 20-inch display size, the idea of using rear-projection for the concept demonstrator was judged inappropriate. By incorporating the 20-inch touch screen with an already-available computer monitor of similar size, we could further economize without losing the ability to demonstrate the UIS concept.

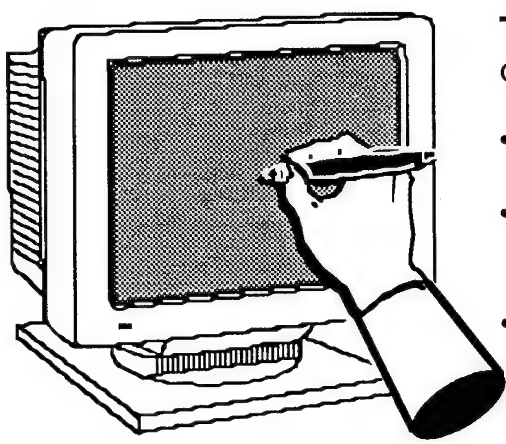
The primary functional limitation of our chosen analog product was a somewhat cumbersome cord tethering the available pen to the touch screen unit. Ideally, the eventual UIS prototype would provide for simultaneous multiple users. Because tethered pens would physically constrain users' ability to work together at one surface, we preferred a cordless pen for the eventual prototype. As of summer 1994, this would have meant using a cordless high-resolution product which senses pen position through a number of membrane layers instead of a single piece of glass. This cordless alternative entailed some negative side effects, including: image degradation derivative from the additional optical layers; higher degree of penpoint-to-display parallax; and a need for optical filtering to reduce reflections at the front surface. In our opinion, these factors made the corded pen the more reasonable alternative for the initial phase of our work. We continued to explore options for a cordless pen which does not degrade image quality, and yet provides the high resolution required of our text recognition software.

We wanted the concept demonstrator's text recognition software to be a commercial product we could re-engineer to operate with our chosen pen-sensor. This turned out to be a very straightforward decision in favor of MacHandwriter™ from Communications Intelligence Corporation (CIC). We judged this product to provide the best out-of-the-box recognition accuracy for medium-sized non-cursive (block) letters at the time of our evaluation. Its introductory pricing ($189) made it a notable cost leader. In addition to providing pen input capabilities, MacHandwriter's stylus afforded all the "point and click" functions of a Macintosh mouse -- thus accomplishing our goal of display control maximally unified with the data input device. Unlike handwriting recognizers which have to be trained to each writer's personal style, MacHandwriter recognizes a diverse but finite set of actions producing printed English block letters and auxiliary characters. Phrased another way, the user must be trained to "feed" MacHandwriter. Although this would seem less sophisticated generally, it actually fit our specifications better than more apparently sophisticated products. It was important that our users be able to make immediate use of the display, with little or no advance training. MacHandwriter's focus on block printing matched the writing style typically employed by collaborators utilizing a conventional whiteboard.

The First-Stage UIS Concept Demonstrator

As a result of our decisions on the tradeoffs listed above, we decided to base the concept demonstrator on an available 20 inch diagonal Sony Trinitron-based monitor attached to a Macintosh IIfx. We obtained a 20-inch glass touch screen unit and integrated the device into the 20" monitor's case. The monitor was disassembled, the touch screen was mounted as closely as possible over the monitor's phosphor screen, and the monitor case was then reconstructed to afford a stable long-term installation. The serial driver circuit board for the touch screen was attached to the side of the monitor and connected to a serial port on the Mac IIfx. A hole was drilled in the monitor on the right side (from the user's orientation) to permit the pen's tether cord to pass through. The pen was docked on the right side of the monitor, with approximately 19.5 inches of tether cord between its rear extreme and the entry point to the monitor casing. This was sufficient to permit unrestricted pen point contact across the entire display surface.

The MacHandwriter package required some hardware-level modifications before we could incorporate it into the UIS concept demonstrator. The commercial MacHandwriter package includes a cordless pen and graphics tablet, from which a data stream is fed to the computer via the Macintosh Apple Desktop Bus (ADB) -- the channel specifically configured for control devices such as the mouse. Our chosen touch screen device (configured for use with an MS-DOS / Windows system) provided for a serial connection (not compatible with Apple's ADB standard). We developed a seamless software interface allowing the concept demonstrator's Mac IIfx to accept the touch screen's output stream via the computer's serial port, treating it as if it had come in via the ADB port, then pass it on as input to the MacHandwriter text recognition software.



The UIS concept demonstrator provides one physical interface surface integrating:

- ***Data Display*** at the monitor screen;
- ***Display Control*** of application software using the pen as a mouse; and
- ***Data Input*** of text by printing with the pen.

Figure 2: The UIS concept demonstrator

As illustrated in Figure 2, the final UIS concept demonstrator had the appearance of an ordinary Mac IIfx with a 20" color monitor. The only visible modifications were the seam where the monitor case had been extended approximately 0.40 inches to permit insertion of the touch screen, the serial driver board attached to the side of the monitor case, and the stylus tethered to the right side of the monitor. A wooden pedestal was constructed to hold the entire apparatus so that the monitor could sit on a shelf 49 inches off the floor. This put the center point of the UIS screen at 60 inches above floor level. A wall partition panel was modified with a 20-inch window matching the position of the pedestal-mounted UIS concept demonstrator, then inserted into one wall of the CDT Lab Group Workspace. The result (seen from within the CDT Lab Group Workspace) was a 20-inch electronic "drawing board" set in the wall.

Some Observations from Using the UIS Concept Demonstrator

This section will report some of the issues we identified during our evaluation of the UIS

concept demonstrator. Most of these are direct results of the affordances of the specific components combined in the concept demonstrator. Each such issue will be presented and discussed with regard to its implications for proceeding to the second-stage UIS prototype.

Overall, the modifications required to patch together the touch screen device and the MacHandwriter software did not seem to lead to degraded performance in the resultant UIS concept demonstrator. Our modified version of the MacHandwriter pen-data recognition system was judged to have recognition accuracy comparable to data read from the higher resolution graphics tablet provided with the standard MacHandwriter package. The occasional delays in recognition (i.e., time lapse between writing and accretion of the character(s) to the text on-screen) did not seem worse with the modified MacHandwriter than with the original package. The ability of the pen to emulate a mouse for control input was the same as in the original package, but its utility was adversely affected by the display's pronounced parallax (described below). These points are good news, and reinforce our confidence in the MacHandwriter type of pen recognition as the preferred base for the second-stage UIS prototype.

Users and visitors found the concept demonstrator relatively easy and straightforward to use. No one found the restriction to block printing a major problem. Most users required 30 minutes minimum to become consistently proficient at text input at a level of about 75% recognition. Some of us had more problems than others in getting MacHandwriter's software to recognize our letters. Writing too small or too fast were two common reasons for recognition failure. Another user problem is best described as consistent failure to print in such a manner as to provide the set and sequence of "strokes" the MacHandwriter software could recognize. This problem eventually was recognized as being worse for the left-handed writers (of which we had an unusually large proportion). Left-handers who deliberately changed their stroke sequence for problematical letters (especially ones with left-right strokes and loops -- e.g., B, b, F, d) were able to improve their proportional recognition performance. We did not do a comprehensive survey of right-handed versus left-handed "tactics" in character entry, but we suspect that the MacHandwriter software is configured with primary attention to the gestural habits of right-handed writers (an admitted majority). The one CDTeam member who had trained an Apple Newton™ to recognize his writing found that MacHandwriter afforded a comparable level of recognition accuracy in a shorter training time, albeit limited to the block printing. These problems are intrinsic to the MacHandwriter recognition software, but they are not sufficiently serious to cause us to look for another such package.

In some ways, the UIS concept demonstrator was more difficult to use than the original MacHandwriter package. With the concept demonstrator, users were required to write on a vertical surface. This was consistently judged less comfortable (for long-term usage) than a horizontal or tilted orientation. The vertical orientation, combined with the relative lack of "friction" between glass screen and hard plastic stylus, made lateral slippage a problem. This slippage made it seem more difficult to control the pen when "writing" on the screen. This slippage and the screen's curvature were sufficient to cause writers problems in maintaining consistent contact between the stylus and the sensor surface. This sometimes caused faults in the handwriting recognition, and it made for problems when using the stylus as a control device for "drag and drop," menu pull-down, and other operations typically requiring continuously depressing a mouse button. These problems will largely persist in the second-stage UIS prototype. The "feel" issue of pen-to-screen contact has been similarly reported for the Xerox Liveboard (Xerox Palo Alto Research Center, 1992). Our planned 40 inch projection surface will be flat (in contrast to the current curved one), and the second-stage prototype should be better with respect to the curvature problem.

Since the UIS was inflexibly mounted in the wall panel, the user had to bear the burden of adaptation -- e.g., to adopt a posture allowing comfortable writing. The placement of the UIS screen's center point at 60 inches off the floor was reasonable, but the degree of "natural" writing affordance was dependent on the individual's height and typical manner of grasping the pen. This

sort of restriction was aggravated by the relatively small writing space provided by the 20" prototype. Compared to a (e.g.) six-foot whiteboard, a user had a much more restricted space in which to write, and he / she could not simply write wherever postural comfort led him / her. We would expect the second-stage prototype to provide a much larger (40 inch diagonal) writing surface, which will in turn offer the user a wider range of writing postures.

The most frequent source of frustration was the parallax resulting from the gap between the monitor's phosphor (display) screen and the glass touch screen. Careful installation had reduced this gap to approximately 0.25" maximum. As the writer's visual angle diverged from a direct line of sight relative to the line between pen point and nearest display pixel(s), the apparent parallax increased. Most of us in the CDTeam were approximately 5'-10" to 6'-0" tall, and simply standing upright was sufficient to induce troublesome parallax. This parallax could be adjusted for as part of acclimatization to the UIS concept demonstrator, but this was not considered a solution. The worst effects of parallax concerned the display control functions -- e.g., pointing and clicking. Even on the large monitor, some features of the Apple Macintosh interface (e.g., close boxes on screen windows) were not easy to "hit" on the first try. The second-stage prototype will have reduced parallax, owing to the direct projection of the data image on the obverse side of the glass touch screen.

We found no conflicts in using Macintosh applications with the UIS concept demonstrator. Problems in controlling applications (e.g., pulling down menus, manipulating windows) were consistently attributed to the novel affordances of the physical implementation described above, and we found no evidence of innate incompatibilities with the applications software. Users had to learn how to switch the pen from control to writing "mode" and vice versa (by tapping the stylus). Confusions over this selection accounted for a number of situational errors while using application programs. We judged this to be an understandable confusion, given that the user could not easily differentiate between control and input based on the device he / she was manipulating at the moment. We consider these problems "pesky" but tractable. User training seemed to alleviate the pen affordance problems with the first-stage prototype, and we assume this will apply to the second-stage unit also.

Issues Affecting Future Research

During the course of our 1994 UIS prototyping, we have uncovered issues and learned of other developments which have a bearing on the viability of our own work. These issues do not shake our confidence in either our analysis of interfaces for group IT nor our general prescriptions for innovation. They do, however, give us reason to reassess what functions a UIS prototype should incorporate, how eventual workaday UIS implementations might differ from our research prototype(s), and how highly our laboratory should prioritize its own independent development of UIS prototypes.

Incorporating Video in the Group Interface

Distributed communications applications (e.g., remote consultation / distance education) add another dimension to the proposed group interface -- the ability to conduct video conferences along with the exchange of data. This final demand involves an additional capacity to capture the video image of a writer at the data input surface for transmission to the remote site. Achieving the desired close coupling of this with the other GI capacities would entail merging the images of the writer / correspondent and his/her data contributions. Work on such jointly shared data / personal channels has been done by Xerox (Videowhiteboard ; Tang & Minneman, 1991) and Japan's NTT (ClearBoard-1; Ishii & Kobayashi, 1992). In both cases, the data was not being captured and transmitted in digital form; its image was transmitted via video. As a result, these projects delivered the natural usability of a whiteboard, but fell short of translating this utility into digital data input.

The evolution of the NTT work into ClearBoard-2 (Ishii, Kobayashi & Grudin, 1992) demonstrated that digital data input could be incorporated into such devices. This is not to say that the ClearBoard-2 prototype approximates our specification for a Group Interface more closely than (e.g.) the Xerox Liveboard. The integration of video into the ClearBoard seems to be prioritized over the elimination of transcription gaps, as illustrated by ClearBoard-2's continued limitation of data input to annotation (as we have defined it in this discussion). Nonetheless, this line of work still bears watching; the vision for the ClearBoard presented in Ishii (1994) clearly implies that elimination of transcription gaps remains a goal of the NTT ClearBoard research and development effort. To the extent this "integrated surface plus video" is a distinguishable extension of our Group Interface ideal, the NTT work must be considered the most advanced effort in that direction to date.

<u>Group Interface Deployment Issues</u>

We have pursued the Group Interface vision with strict regard to an extreme interpretation -- i.e., a single artifact embodying all the functions of currently disparate interface surfaces at one physical surface. While this has proven to be successful in getting across our point, one might well question whether this extreme of integration is likely to be reflected in the derivative products eventually marketed and installed. To phrase it another way, we ask whether the ability to merge all functions at one physical surface (as a research product) determines the "attractiveness" of such a solution (as a marketable product). During the course of our Group Interface work, we have identified some issues which require us to qualify our commitment to the prototyped deployment style (an all-in-one surface) as a literal sample of the probable (marketed and installed) deployment style. In this section, we shall outline some of these issues. It is critical to point out that these issues do not affect our commitment to the idea that effective group interfaces will entail (1) integration of functional engagement surfaces into a minimal set or (2) minimization of functional gaps between data images and base data. The following issues only pertain to our predictions about the eventual appearance of group interface products meeting these goals.

One problem with a conventional whiteboard is that one must get up from the conference table and walk up to it before one can add data to it. Wouldn't it be more convenient to allow multiple users to access the mutual data display from their seats? The Xerox Liveboard™ permits this to some extent by using a cordless infrared pen for input. Users need not physically touch the Liveboard to manipulate its display or add an annotation. However, the Liveboard approach only permits single channel input, thus minimally trading the physical effort of walking to the Liveboard for the physical effort of handing off the pen device. While walking to the board may seem the more involved of the two tactics, it must be pointed out that in a meeting situation this physical "taking to the floor" would presumably coincide with procedurally "getting the floor." The additional physical effort might well be justifiable on the grounds of its reinforcement of conversational tactics. Because turn-taking and other behavioral mediations in conversation remain active CSCW research issues, we do not believe this tradeoff can yet be resolved.

Conversational aspects of user proximity to the Group Interface notwithstanding, one might ask whether a solution permitting direct input to a common display from an individual's seat is already the case in computer-supported meeting rooms (e.g., in Capture Lab and other GSS facilities). In effect, it is -- provided one is willing to fall back to a deployment scenario in which the three functional engagement surfaces are manifested at a similar or greater number of physical surfaces (e.g., group display, individual display, keyboard, and mouse). This is yet another illustration of the tradeoff we have delineated between interface surface integration and transcription gaps. In the best case, current computer-supported meeting rooms minimize the transcription gap (via direct data input) at the expense of effort required to effect and coordinate actions among disparate interface surfaces. Such facilities' purported productivity gains (as these pertain to generation and manipulation of common base data -- cf. Nunamaker *et al.*, 1991) can be

construed as deriving from minimal transcription, while their demonstrable human factors shortcomings (cf. Bannon, 1994; Whitaker, 1994) can be attributed to the affordances of their deployed interface surfaces.

The issue then becomes: How can we (1) obtain the minimal transcription costs of current GSS facilities *and* (2) maximally integrate functional interface surfaces *without* (3) necessarily requiring all physical interactions to be effected at one common physical surface? The solution is to reframe the thrust of point (3) and require all physical interactions to be effected at one physical surface *per individual*, the sum of which comprises one *virtually* common surface for logical / manipulative engagement. In other words, give each meeting participant his or her own integrated physical / functional surface (e.g., a pen-based slate) tied into a common network such that the summary set of all such individual units plus common display(s) provides the physically distributed equivalent of a functionally unified surface.

An example of such a deployment scenario could be accomplished using an integrated array of (e.g.) Apple Newtons™ and Xerox Liveboards. Such an approach represents the state of the art in both this line of HCI enquiry and today's commercial marketplace. It has been instantiated at only one facility to date -- the Integrated Publication and Information Systems Institute (IPSI) at the German National Research Center for Computer Science (GMD) in Darmstadt. Effective November 1994, the second-generation meeting facility for the DOLPHIN meeting support suite came on-line, extending that work already approximating the above-delineated solution reported in Streitz *et al.* (1994). As of the date of this writing, the GMD facility must be considered the group support research facility most advanced toward the group interface vision we have delineated.

<u>Parallel Commercialization Issues</u>

As we have noted, some artifacts closely analogous or relevant to our Group Interface vision (e.g, the Apple Newton™, the Xerox Liveboard™) are already being marketed. These commercial products, with additional local modifications, have been integrated to form the GMD meeting facility which we identify as the state of the art in terms of GSS interface capacities. Our own UIS prototype was constructed by taking commercial products and adding local effort to overcome compatibility problems. While our formulation of the Group Interface vision may be on a par with anyone's state of the art, our realization of that vision is not assured to be first or finest. We found out late in our UIS development effort that the functionality of our prototype is in fact already being delivered commercially, albeit on a custom-built basis. The following information was provided us under a condition of confidentiality, and neither the contact person nor any other party mentioned will be identified.

At the CSCW'94 conference in Chapel Hill NC (October 1994), the lead author was approached by the president of a Canadian firm which is one of the largest commercial vendors of electronic whiteboard products. This person had learned of the CDT Lab's research interests along this line (based on the lead author's earlier interactions in the CSCW community's interpersonal networks). He revealed that his company had built approximately six large (60 inch diagonal) rear-projection electronic whiteboard units (similar to the Xerox Liveboard) modified at customer request to incorporate handwriting recognition at the screen surface. Not one of the six custom units was requested by or delivered to a North American customer; they all went to Europe or to Japan.

The contact person's company, too, had chosen the CIC block printing recognizer as the support software of choice. He noted the primary development problems as having been bus-level driver data streams, calibration, and coordinating the sampling rates for the input screen and the writing recognition software. In these respects, his company's experience paralleled the CDT Lab experience. The contact gave an estimated retail cost of $18,000 to $20,000 for a complete such custom unit (exclusive of computer and projection equipment). Given our own vendor estimate of

some $10,000 for a 40 inch diagonal touch screen alone (to be installed in the second-stage UIS prototype), the cost for this commercial unit was not unreasonably high.

CONCLUSIONS

This technical report has summarized one technology-oriented component of the Collaborative Design Technology Laboratory's work during the period 1993-1995. This work has addressed the human factors aspects of supporting groups with information technology by:

- outlining the relevant background issues and state of the art in group IT support;
- laying out a research strategy overcoming prior HCI oversights in this area;
- generating an analytical framework appropriate to the problems we identified with the current state of the art;
- applying that framework to delineate the necessary design tradeoffs in progress toward innovative Group Interfaces;
- presenting a prototype of a Group Interface artifact (the Unified Interface Surface); and
- discussing our experiences during usability evaluation of the UIS.

Furthermore, we have addressed the practical aspects of Group Interface development with respect to issues of current concern (video, deployment, and commercialization). Briefly stated, our work is consistent with lines of research already well underway at CSCW research centers in Germany and Japan. At the time of this writing, those foreign efforts must reasonably be considered the state of the art in Group Interface research and development. Through personal contacts, we have learned that custom-built commercial units providing functionality equivalent to our projected second-stage Unified Interface Surface prototype are already being sold by a Canadian firm to clients in Europe and Japan. More importantly, these commercial units are being produced at a price comparable to the projected retail cost for building a second-stage UIS unit from scratch.

The good news is that these developments reinforce our confidence in our problem assessment and proposed solutions. The "not-so-good news" is that our UIS effort may have only temporarily placed us at a vanguard position in this area. We do not currently have sufficient resources to compete with the other research centers listed above. Due to those centers' foreign locations, our ability (as a USAF component) to pursue collaborative arrangements with them is limited. As a result, continuance of our Group Interface research is in question at the time of this writing. This is not necessarily bad news per se -- the pursuit of the leading edge usability research in Europe and Japan ensures that realization of our Group Interface vision is still possible, and commercial demands for Group Interface units lead us to hope that market forces will hold down the entry cost for deploying such technology.

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